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A
PRACTICAL TREATISE
ON
LIGHTNING PROTECTION.

SPANG.

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A PRACTICAL TREATISE ON LIGHTNING PROTECTION.

GIVING COMPLETE AND EXPLICIT INSTRUCTIONS FOR THE
PROTECTION OF BUILDINGS AND EXPLAINING THE
DEFECTS OF THE LIGHTNING CONDUCTORS
NOW ERECTED.

BY

HENRY W. SPANG.

With Illustrations.

New and Revised Edition.

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PREFACE.

THE following treatise is based upon observation and facts, and is the only work which fully and properly explains the action of the electricity of the air and earth, while uniting during a lightning discharge.

It contains more complete and explicit directions for applying lightning-conductors to buildings than those given in the treatise issued by me in April, 1877, or contained in any other work. It is issued with a view of effecting a general introduction of the radial systems of lightning-conductors herein described, which are patented and endorsed by the most prominent electricians and scientists, and will, beyond doubt, supersede the unreliable systems of lightning-conductors heretofore employed, many of which have no less than four serious defects.

The persons heretofore engaged in the business of manufacturing and erecting lightning-conductors have not thoroughly and properly investigated the action of the electricity of the air and earth while uniting during a lightning discharge, and, consequently, have not constructed and applied them to buildings, etc., in a proper manner. They have, erroneously, been governed by experiments with artificial electricity, which are not legitimate illustrations of the action of the electricity in a lightning discharge.

The author has had a practical experience of over twenty years in the electrical business, and has given the subject of lightning protection considerable attention.

He is confident, when the radial systems of lightning-conductors herein described are employed, and applied to buildings, etc., in accordance with the directions given, that absolute protection to life and property will be effected.

HENRY W. SPANG.

READING, PA., July, 1883.

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A

PRACTICAL TREATISE

ON

LIGHTNING PROTECTION.

Introductory.

IN order that the reader may have a proper knowledge and comprehension of the electrical laws and principles in accordance with which lightning-conductors should be constructed and applied to buildings, etc., the principal technical terms used in the electrical science, certain properties and relations with which electricity is endowed, also the principal known facts relating to the electricity of the atmosphere and earth, and to the destructive discharges, commonly known as lightning, which take place between them, are first explained. After which, general information in reference to lightning-conductors is given, including complete and explicit directions for their proper construction and application to buildings, also a full explanation of the defects of those heretofore employed.

Notwithstanding the failure of many of the lightning-conductors heretofore erected to afford protection, and the prejudices existing against their employment, it remains an undoubted truth that the large number of lives and vast amount of property that are needlessly jeopardized can, with certainty, be protected from injury or damage by lightning.

Electricity and its Action.

ELECTRICITY is one of the great forces of nature pervading the air, earth, and all matter, and is as universal in its effects as are light and heat. It was first noticed by Thales, of Miletus, the founder of Ionic philosophy, about 600 years before the Christian era. He observed that when amber was subjected to friction, it acquired the power of attracting light substances, such as small pieces of feathers, paper, etc., and on this account was led to attribute to it a species of vitality. Its name is derived from *elektron*, the Greek word for amber.

We are cognizant of its existence, but we do not know its particular form any more than we know that of sound or light. It is, however, subject to laws as definite and invariable as those which govern the motion of the planetary system. Adopting the views of the eminent electrician, Faraday, who considered electricity as "an axis of power having contrary forces, exactly equal in amount, in contrary directions," scientific men of all nations now recognize two kinds of electrical force, which are distinguished by the terms *positive* and *negative;* but they do not assume the existence of any particular kind of matter to which the term electric fluid may be applied. The positive electrical force is generally indicated by the algebraic sign + (plus), and the negative by the sign — (minus).

In the natural state of a body, the two electrical forces are supposed to be equally balanced or distributed, or, in other words, every portion of the body contains the same amount of each of the two electrical forces, thereby forming an equilibrium between them, and they are then said to be *neutral,* or inactive.

The electrical equilibrium of a body may be disturbed by friction, chemical action, changes of temperature, and other causes; and then the two electrical forces will be separated, the positive accumulating in one portion of the body, and the negative in another, and in such case electrical action is exhibited, and the body is then said to be *electrified,* or charged with electricity.

When a body, or part thereof, contains all positive, or more positive than negative electricity, it is said to be positively electrified or charged; and when it contains all negative, or more negative than positive, it is said to be negatively electrified or charged.

Electric quantity is the term applied to the amount of electricity present. *Potential* (heretofore generally termed tension) implies that function of electricity which determines its motion from one point to another, and the difference of potential, which determines the amount of this motion, is known as *electro-motive force.*

When the two opposite electricities are accumulated on bodies separated from each other, and are in a state of rest, they are said to be in a *static* state; and when they rush towards each other, to restore the equilibrium between them, they are said to be in a *dynamic* state. In the static state they reside upon the surface of the bodies, while in the dynamic they pervade every portion of the body through which they pass.

The rushing together and uniting of the two opposite electricities is known as a *discharge;* and when the discharge takes place over a good conductor, it is generally termed a *current,* and the path over which a current of electricity flows is known as the *circuit.*

Resistance is the term applied to the opposition or obstacle opposed to the passage of electricity by the substance or body through which it passes. It is the inherent property of every substance. The various metals offer a low resistance and permit electricity to flow freely through them, and are termed *conductors,* while stone, brick, wood, dry earth, glass, gutta-percha, and the air offer a high resistance to it, and retard its flow, and are termed *non-conductors* or *insulators.* Well burnt charcoal, metallic ores, coke, water, and vapor are medium conductors; and all the so-called non-conductors or insulators allow electricity to flow through them, to a certain extent.

Bodies charged with the same kind of electricity repel each other, but when charged with opposite electricities, there is a mutual attraction and disposition to unite and form an equilibrium between them. This is the fundamental law of electric action. Electricity manifested by different means is characterized by different properties. The electricity manifested by ordinary friction has a high potential, and is able to readily overcome the resistance of poor conductors, while its quantity is small, and therefore produces weak magnetic and mechanical effects.

On the other hand, the potential of the electricity manifested by the chemical action in a galvanic cell or battery is low, and cannot overcome great resistance, while its quantity is great and is capable of producing powerful magnetic and mechanical effects.

Electric Induction.

When a body is electrified, positively or negatively, and is brought within a suitable distance of another body, and particularly one of good conductivity, which is in its natural or neutral state, the electricity of the former will, by a peculiar influence, cause the two electricities of the latter to be separated, repelling the electricity of the same phase, and attracting that of the opposite phase.

Suppose P, in Fig. 1, to be a positively electrified body, and N P a body previously in a neutral state, at a distance. The action at P is transferred to N P through the medium of the molecules of the intervening poor conductor which separates them, each of which becomes *electro-polar*, or disposed in an alternate series of positive and negative electrical poles or states, as indicated by the series of black and white hemispheres.

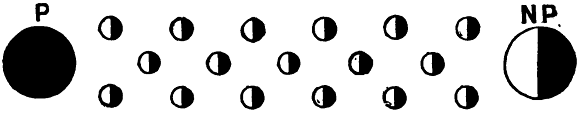

Fig. 1.

Again, let three insulated metallic spheres, A, B, C, be placed in a line, but not in contact with each other, as shown in Fig. 2.

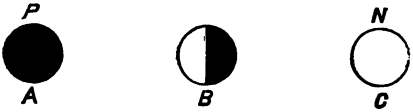

Fig. 2.

Let A be positively electrified, and C be uninsulated. Under these circumstances, B will acquire the negative state at the surface towards A, and the positive state at the surface farthest from it, and C will be charged negatively.

The ball, B, will be in what is called a *polarized* condition; that is, the opposite parts will exhibit the opposite electrical states.

This peculiar influence is known as *electric induction*, and bodies in this state are said to be electrified or charged *by influence.*

According to Faraday, "it is of the most general influence in electrical phenomena, appearing to be concerned in every one of them, and has in reality the character of a first, essential, and fundamental principle."

"It appears to be essentially an action of contiguous particles, through the intermediation of which the electric force, originating or appearing at a certain place, is propagated to or sustained at a distance, appearing there as a force of the same kind, exactly equal in amount, but opposite in its direction and tendencies."

The term *dielectric* is applied to the substance or medium through and across which electric inductive action occurs.

Faraday having proved that electric induction always has a dielectric, supposes the particles or molecules of the dielectric to be conductors insulated from each other.

He also considers that the particles or molecules of a good conductor are polarized exactly in the same way as those of air, glass, and other poor conductors,—the only difference being, that the particles of a good conductor can communicate their electricities to each other much more readily than those of a poor conductor.

The Formation of Thunder-Clouds and Storms.

THE formation of clouds is due to the meeting of two currents of air of different temperature, which causes a condensation of the aqueous vapor in the atmosphere.

There is always an exchange of air between two places of different temperature. The warm air flows toward the cold place, and the cold air flows in an opposite direction toward the warm place; and the greater the difference in temperature between the two places, the greater is the velocity of the currents of air in the interchange.

According to the theory advanced by Prof. Wm. Blasius, a storm consists in the movement of the air caused by its tendency to reëstablish an equilibrium which has in some manner been disturbed; and all such movements, whether they are gentle breezes or furious hurricanes, accompanied by more or less condensation of moisture or clouds, or even by none at all, may be called storms. A thunder-storm generally occurs during warm weather, and particularly after a long dry spell, and is due to the rapid movement of the polar or cool aerial current toward the south. Irregular currents of the polar air, in advance, shift over the surface of the earth, and bank up and lift the equatorial or warm air in an irregular manner, producing irregular masses of clouds of the rounded, mountain-like form. As the polar current progresses toward the south, the condensation of vapor increases and begins to be precipitated, and sometimes takes place so rapidly and on so large a scale that the whole process becomes plainly visible.

The great violence with which the equatorial current rushes over the polar current, so different in temperature and density, no doubt produces by friction a great quantity of electricity, so characteristic of these storms.

During a snow-storm, accompanied by a high wind, electricity is also greatly generated in the air, thereby indicating that friction, caused by the rapid movement of the air in connection with condensed vapor or snow, is one of the principal causes of the production of atmospheric electricity.

Height of Thunder-Clouds and Area of Storms.

THE distance between the lower part of thunder-clouds and the earth has been found to vary from 600 to 26,000 feet, according to the topography of the country and other circumstances. In this country, the average height of the said clouds above the earth is estimated at 2500 feet. It is only in the so-called cloud-burst, a tornado or rotary storm, that the cloud reaches the earth, and then produces pitchy darkness.

The area of thunder-storms depend upon the configuration of the earth's surface, and also vary with the latitude and longitude and general climatic conditions.

In the United States of America, north of the Gulf of Mexico and South Atlantic States, they generally extend in width about twenty to fifty miles, though often exceeding fifty and sometimes one hundred miles. Their depth is usually from three to five miles, and in some cases they pass over the earth for a distance of about five hundred miles. When the cold polar wave advances over the low ground and water-courses in a valley, the width of the storm conforms to the breadth of the valley; and if the wave divides by flowing through two or more valleys, more or less parallel to each other, then there are so many storms abreast of each other, leaving the mountain ridges between them.

The number of thunder-storms diminishes as we approach the polar regions, so that they no longer occur in the latitude of seventy degrees.

Electric Induction during a Thunder-Storm.

ELECTRIC induction takes a prominent part during a thunder-storm, and through its influence the route is determined over which a disruptive discharge takes place between a cloud and the earth, or between two clouds or layers of a cloud.

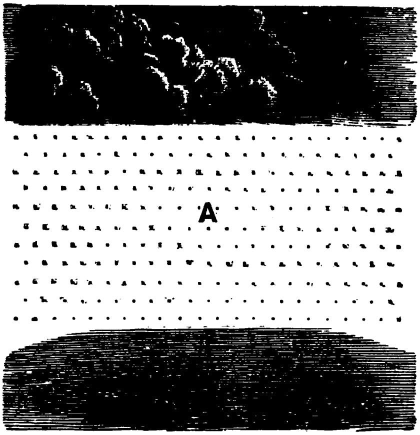

Fig. 3.

When a highly positively electrified storm-cloud, C, Fig. 3, is within about 3000 feet of the earth, E, it causes, by induction acting through the vapor particles, A, of the intervening air, the earth beneath and everything thereon to become intensely negatively electrified, separating the combined electrical forces of the earth and objects thereon, repelling the force of the same phase and attracting that of the opposite phase.

The area of earth intensely electrified by induction being equal to the area of clouds above in which the electricity is greatly accumulated.

The clouds during a thunder-storm are sometimes so dense and highly charged with electricity, that they cause, in the midst of the obscurity, a vivid light to rest on bodies upon the surface of the earth. Mention is made of luminous rains, during which the ground seemed to be on fire. Travellers have on a number of occasions been seized with alarm on seeing their wet clothes all aglow on stormy nights.

These luminous effects are caused by the inductive influence of the electricity in the said clouds, which causes the electricity of the earth to manifest itself. While in the act of discharging into the air, the electricity of the earth has often been seen tipping with light, in the form of a star or brush, the masts and spars of ships, also edging with light the manes of horses, the metal trimmings of their harness, the lashes of whips, the brims of hats, the tops and edges of umbrellas, the sharp points of swords and lances, the extremities of hair and whiskers, the corners of chapeaux, the buttons upon the coat, filaments of straw, the beaks of birds, and the myriad needle-like terminations of vegetable growth, with that incomparable point and finish which they took from Nature's own hands.

Atmospheric Electrical Discharges.

WHEN the attraction between the positive electricity of a cloud or clouds and the negative electricity of the earth, or *vice versâ*, is able to overcome the resistance offered by the intervening air, a rushing together and uniting of the said opposite electricities takes place, which is known as a discharge, and effects the restoration of equilibrium between the said electricities. The route of such a discharge is a winding one, like a screw-thread or a stretched-out spiral, while to a person upon the earth it appears to pursue a zig-zag course through the air. Discharges also take place between the opposite electricities contained in two clouds or layers of a cloud.

The large number of electrical discharges during a thunder-storm, in its passage over the earth, indicate that there is a rapid and constant condensation of aqueous vapor, also a great generation and accumulation of electricity in the clouds formed along its route. Several cases of death by lightning have occurred under circumstances from which it is supposed that a circuit is sometimes formed during a storm, which extends over many miles, so that when a downward discharge occurs at one point, through the power of electric induction at another point, which may be several miles away, a corresponding discharge in the reverse direction takes place, as shown in Fig. 4.

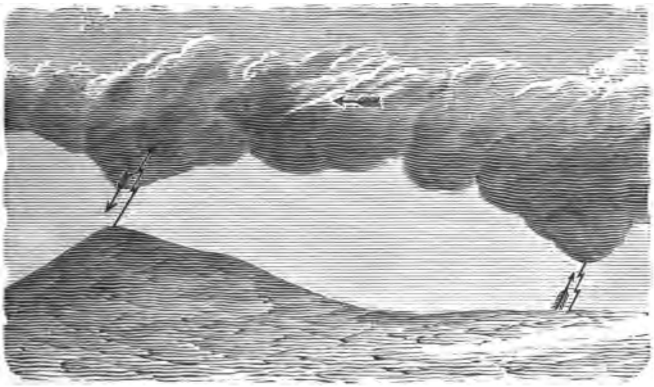

Fig. 4.

Lightning and Thunder.

Lightning is the name given to the illuminating or vivid flash of light produced by an atmospheric electrical discharge. The light we see is the effect of a discharge, and is due to the resistance offered by the atmosphere to the passage of electricity. The greater the resistance offered by the air, the greater is the heat developed, and more distinct is the light.

The positive and negative electricities of the air and the earth rushing toward each other and uniting, cause the air to be thrown into vibrations by the sudden separation and reunion, producing the violent report and rumbling noise known as thunder.

Lightning and thunder are almost simultaneous, but an interval of several seconds is always observed between them, which arises from the fact that sound only travels at the rate of about 1100 feet per second, while the passage of light is almost instantaneous.

Accumulation of Electricity in the Subterranean Water-bed.

THE electricity of the earth, as well as that of the air, accumulates greatest where the largest amount of moisture is present.

In the earth it is principally confined to the subterranean water-bed, also to rivers and other bodies of water.

That the electricity of the earth is principally accumulated in the subterranean water-bed, and not in the dry surface soil, as has generally been supposed, is quite evident from the fact that where the water-bed has been at a depth not exceeding about seventy feet, the electricity from the water-bed has marked its path through the surface soil by throwing up the earth, also rending solid rock asunder and allowing the flow of water from the water-bed through the fissure or fissures.

The modifications that have taken place in the underground waters during thunder-storms, are also evidence that the principal charge of electricity exists in the subterranean water-bed. Springs have become troubled and overflowed, even after a great drought. Deep wells have been heard boiling and bubbling noisily, and fountains have leaped from the rock with sensibly augmented projectile force. Historians and meteorologists mention local inundations, which could not have been brought about by the small quantity of rain issuing from the clouds, and falling within a certain radius. Upon such occasions immense masses of water have been seen rising from the bowels of the earth, for a greater or less period of time, after a violent thunder-storm, from openings until then unknown, which were undoubtedly caused by the fact that the electrical charge being concentrated in the water-bed, was greatly disturbed during the thunder-storm by the discharges between the clouds and the earth, and greatly agitated the water therein, and allowed it to flow through the fissures made in the earth by the electricity.

Miners, at work at a great depth in the earth, have received violent shocks during thunder-storms, owing to the electricity contained in the water-bed rushing upward to unite with the opposite electricity descending from the clouds.

Where the water-bed is at a great depth, especially in sandy districts, the electricity from the clouds has marked its path through the sand to unite with the electricity from the water-bed by making hollow vitreous tubes therein.

The tubes are coated on the interior with a brilliant glass surface, caused by the intense heat of the electricity. They have been found to vary from five to about seventy-five feet in depth, according to the distance the subterranean water-bed is beneath the surface of the earth. They are generally winding in form, often throwing out lateral spurs or branches, and contracted in size toward the lowest extremity. The diameters of the main tubes vary from four-hundredths of an inch to three inches and a half, and they are often many yards in length. The thickness of the sides varies from one-fiftieth of an inch to nearly an inch. These formations have received the name of *fulgurites*, and are of quite frequent occurrence upon the sandy plains of Silesia, where they were first discovered.

If the electricity of the earth existed principally in the surface soil, these tubes would not have been formed, as the electricity of the air would have been diffused when it reached the earth.

Action of Electricity of Air and Earth during a Lightning Discharge.

In determining the action of the electricity of the air and earth while uniting during a lightning discharge, scientists have erroneously been governed by experiments made with the Leyden jar or a prime conductor of a frictional electrical machine. The small quantity and area of accumulation of electricity, as well as the short distance between the opposite electricities in such experiments, are quite infinitesimal, compared with the great quantity and area of accumulation and long distance between the opposite electricities contained in the clouds and earth.

Experiments with artificial electricity cannot possibly demonstrate the action of the electricity of the clouds and earth during a lightning discharge, and therefore are not proper and practical illustrations thereof.

It is asserted by aeronauts who have been in and above the clouds during a thunder-storm, that when there is a lightning discharge between the lower part of the clouds and the earth there is a simultaneous and concentrative flow of electricity in the clouds toward the lower layer thereof.

From observations made by the writer during the past twenty years, he has found that there is a strong flow of electricity from all directions in the earth, within a radius of about 3000 feet, toward a central point, as shown in Fig. 5, in line with which the electricity of the air and earth unite during a lightning discharge. This concentrative flow of electricity of the earth during a lightning discharge, also the great expansive action of the electricity from the clouds as it approaches the earth, is manifested by the following phenomena: The great affinity of the electricity of the clouds and earth for a herd of cattle, a large assemblage of persons, a large quantity of hay, grain, ice, powder, or other material in bulk, a large body of water, a large deposit of ore in the earth, a metal roof with its rain-pipes connected with metallic drain-pipes leading into sewers in the earth,

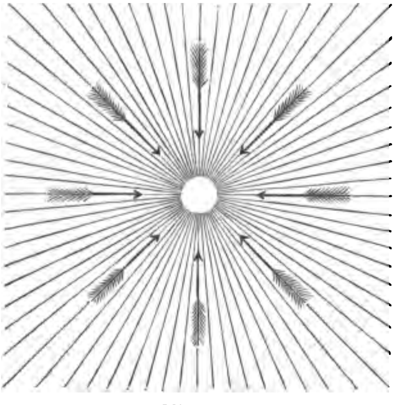

Fig. 5.

an oil-tank with its underground pipes, also for telephone lines in cities and towns which radiate in different directions and terminate in the earth in the said places.

The shattering of telegraph or telephone poles for a long distance by a single lightning discharge, when unprotected by lightning-conductors.

The breaking of the electric current through thick walls between the gas- and water-pipes upon the inside of buildings and the ordinary lightning-conductors upon the outside thereof. In the case of the All Saints' Church in Nottingham, England, about thirteen years ago, the electricity from the clouds descended in line with the lightning-conductor, and that from the earth, which principally concentrated upon and flowed along the underground gas-mains, united by breaking through a wall of solid masonry, four and a half feet thick, which separated the lightning-conductor upon the outside of the building and the gas-pipe upon the inside thereof.

The frequent killing or injuring of every person or animal within fifteen feet of the base of a tree, and the shattering of all the masts of a vessel by a lightning discharge, as was frequently the case before the application of lightning-conductors to the masts, also the many instances of lightning discharges taking place in line with the hay and grain stored in the lofts of barns, not only demonstrate the said concentrative flow of electricity in the earth and water, but also the great upward tendency of the said electricity as it approaches that descending from the clouds, and the great expansive action of the electricity from the clouds as it approaches that concentrating in or arising from the earth.

The Path Selected by a Lightning Discharge.

It must not be supposed that the electricity accumulated in the thunder-clouds and that contained in the subterranean water-bed pursue an experimental path through the intervening air, objects, and surface soil to unite with each other; on the contrary, before the slightest movement has taken place, the said electricities have, by induction, selected the shortest and best path which they will take, passing over such objects upon and in the earth which offer the widest and easiest scope for the concentrative flow of electricity in the earth to unite with the electricity descending from the clouds.

A lightning discharge will invariably take place in line with a tree, man, or animal in an open field, a ship or vessel upon the sea or other body of water, a spire of a church, a flagstaff, chimney, and any other elevated projection of a building, and particularly in line with a building having a metal roof and metal rain-pipes electrically connected with the earth, also with one filled with hay, grain, ice, or other material in bulk, for the reason that they offer the shortest and best route and the widest scope for the electricity of the clouds and earth to unite.

Under certain favorable conditions at two or more points upon the earth within a radius of about 2500 feet, the electricity from the clouds will fork or separate into two or more branches before it reaches the earth, and unite with that of the earth at as many points, varying from 20 to 2000 feet apart, and thereby giving rise to the so-called "freaks" and "lateral discharges."

The Origin and Principal Function of a Lightning-Conductor.

The celebrated American philosopher, Benjamin Franklin, was led to the idea of the lightning-rod or conductor by the tendency which lightning discharges have for taking place in line with the tops of the spires of churches and masts of ships—in fact, all projecting bodies pointing toward thunder, or rather electrified clouds.

During the year 1749, he made a series of experiments with a Leyden jar, by which he found that pointed metallic conductors gave off and received electricity with great rapidity, and when the electricity in the jar was discharged by means of a sharp point, there was not that snapping spark which occurs when the jar is discharged by a ball or the blunt end of a rod.

After detailing the results of these experiments in a letter, dated July 29th, 1750, to his London correspondent, Mr. Peter Collinson, for communication to the Royal Society of England, he says:

"If these things be so (referring to the discharging power of points), may not the knowledge of this power of points be of use to mankind in preserving houses, churches, ships, etc., from the stroke of lightning, by directing us to fix on the highest points of these edifices upright rods of iron, made as sharp as a needle, and gilt to prevent rusting, and from the point of these rods a wire run down the outside of the building into the ground, or down round one of the shrouds of a ship, or down her side till it reaches the water? Would not these points probably draw the electrical fire silently out of the cloud before it came nigh enough to strike, and thereby secure us from that most sudden and terrific mischief?"

The opposite electricities of the lower strata of the air and the surface earth continually recombine silently, principally by the intervention of bodies upon the surface of the earth, such as trees, and particularly those upon the tops of hills and mountains.

When a metallic conductor is well connected with the earth and extends above the highest projecting point of a building, it will silently establish the equilibrium between the electricity of the earth and that contained in the lower strata of the atmosphere in the immediate vicinity of the conductor; in fact, a continuous current of electricity will flow over the conductor, not only during a thunder-storm, but also during clear weather; and the strength of the current will vary with the potential of the electricity of the atmosphere.

Instances can be cited where there has been a diminution of lightning discharges after the application of lightning-conductors to the spires of churches and other high structures.

It has, however, been fully demonstrated that, owing to the long distance of most of the thunder-clouds from the earth, their large area and great accumulation of electricity therein, a lightning-rod or conductor with one or more points at its top, also points along its entire length, cannot, as a rule, perform the function, suggested by Franklin in 1750, of silently tapping the electricity contained in a cloud and preventing lightning discharges taking place in the vicinity of the building, and particularly one of the ordinary height, to which it is applied.

The fact that lightning discharges have quite frequently taken place between thunder-clouds and the tops of lightning-conductors erected upon some of the highest steeples in the world, and which were well connected with the earth, is sufficient evidence that thunder-clouds are generally very high, and that the lightning-conductor cannot always perform the function generally claimed for it by the lightning-rod men and scientists.

The principal object and function of a lightning-conductor therefore consists in furnishing a better path and scope for the passage of the electricity between the clouds and the earth, than the path and scope offered by the objects which are to be protected.

The first lightning-conductor ever erected was set up by Franklin himself in September, 1752, and applied to his house in Philadelphia, and, after an experience of fifteen years with lightning-conductors, it became apparent to him that a pointed metal rod could not always perform the function suggested by him in his letter of 1750. In a paper on Lightning, and the means for protecting buildings and persons, written by him in September, 1767, while in Paris, he says: "The clouds have often more of this fluid in proportion than the earth; in which case, as soon as they come near enough (that is, within the striking distance), or meet with a conductor, the fluid quits them and strikes into the earth.

"An iron rod being placed on the outside of a building, from the highest part continued down into the moist earth, will receive the lightning at its upper end, attracting it so as to prevent its striking any other part, and affording it a good conveyance into the earth, will prevent its damaging any part of the building.

"Thus the pointed rod either prevents a stroke from the clouds, or, if a stroke is made, conducts it to the earth with safety to the building."

Reliable Lightning-Conductors.

THE following metallic conductors are capable of safely conveying the electricity in a heavy lightning discharge, and when well connected with the earth and applied to a building in a radial system, as hereafter recommended, will effect proper protection:

A metal roof, iron front and cornice, stack, cupola, and any cast or rolled iron pipe or bar extending from the roof to the ground floor of a building.

A sheet-iron pipe or band, with soldered or tight-fitting joints, and made of plates not less than 12 inches long, and weighing not less than .50 of a pound per lineal foot.

		Weight per sq. foot.
Iron plate, coated with tin or other metal.	IC brand = $\frac{1}{80}$ inch in thickness	.52
	IX " = $\frac{1}{64}$ " "	.64
	IXX " = $\frac{1}{55}$ " "	.74

		Weight per lin. foot.
Rain-pipes:		
Cylindrical, 3 inches in diameter,	IC brand	.47
Rectangular, 2¾ by 2 inches,	IX "	.58
Of tin or terne plate, 10 inches wide,	IXX "	.66
Cylindrical, 4 inches in diameter,	IC "	.63
Rectangular, 4 by 2¾ inches,	IX "	.78
Of tin or terne plate, 14 inches wide,	IXX "	.90
Corrugated, 3 inches in diameter,	of No. 30 B. W. G.	.55
" 4 " "	sheet-iron, galv.	.74
Gas-pipe, inside diameter, ⅜ inch		.56
" " " ½ "		.85
" " " ¾ "		1.12
" " " 1 "		1.67
Flat iron bar, 1½ by ⅛ inch		.63
" " 2 " ⅛ "		.84
" " 2½ " ⅛ "		1.04
" " 3 " ⅛ "		1.25
Round iron bar, ½ inch, for air terminals		.66
" " ⅝ " " "		1.03
Galvanized sheet-iron band, 6 inches wide, No. 23 B. W. G. in thickness		.60
" " " 6 " " " 20 " "		.88
" " " 9 " " " 27 " "		.65
" " " 9 " " " 23 " "		.89
" " " 1 foot " " 30 " "		.63
" " " 1 " " " 27 " "		.88
Cable of	Seven No. 8 B. W. G. galv. iron wires	.52
	Eight " 9 " " " "	.53

The weight of the rain-pipes named include a well-soldered seam. The cylindrical and rectangular rain-pipes have generally been made of IC and IX tin and terne plate, fourteen and twenty inches long, and the corrugated rain-pipes of No. 30 B. W. G. sheet-iron, galvanized, thirty-six inches long. If the said rain-pipes would be made of plates, IXX brand, or No. 27 B. W. G. in thickness, including the tin or zinc coating, and about thirty-six inches long, they would be more substantial, and better adapted for the passage of the electricity in a heavy lightning discharge.

Nearly every writer on lightning-conductors has asserted that copper is the proper metal for a lightning-conductor, and that a copper conductor is about six times better adapted for a lightning discharge than one of iron of the same size. Pure copper offers about six times, and the ordinary commercial copper about four times, less resistance than iron to a galvanic current, or electricity of a low potential; but a lightning discharge which is electricity of a very high potential, is able to overcome ordinary resistance very readily. Really, the difference between the conductivity of copper and iron to the electricity in a lightning discharge is so small that it practically amounts to nothing.

Iron is many thousand times a better conductor of the electricity in a lightning discharge than wood, brick, stone, and other material of poor conductivity, of which buildings are usually constructed, provided a sufficient quantity thereof is employed in a suitable form and placed in a short and direct route between the points of the discharge. Its advantages over copper are cheapness, greater resistance to mechanical injury and high temperature of fusion (2.786° Fahrenheit as compared with 1.994° for copper). It is also less tempting to the thief, who has on a number of occasions stolen part of the copper conductors erected upon buildings, thereby breaking their continuity and making the remaining portions useless.

Two dissimilar metals, like copper and iron or zinc combined, should be avoided in the construction of any part of a lightning-conductor which is exposed to constant or excessive moisture, as a chemical action caused by the moisture takes place between them —the same as in a galvanic cell or battery—causing the iron or zinc to be eaten away, and eventually nothing is left but a small quantity of copper.

Sheet-iron conductors should be coated with zinc, tin, or any other suitable metal, and painted, in order to prevent them becoming rusted. The parts of other iron conductors should be joined together by means of slip, screw, or other tight-fitting joints, and, whenever convenient, they can be soldered. Paint, or an ordinary amount of rust, upon the surface of a conductor does not affect its conductivity, and when rust, paint, or any other substance exists at a tight-fitting joint, the electricity in a lightning discharge can readily pass over it.

The Radial System of Lightning-Conductors.

When we consider the concentrative and upward action of the electricity of the earth and the expansive action of that from the clouds, during a lightning discharge, as hereinbefore explained, also the failure of the lightning-conductors as heretofore erected, it is quite evident that, in order to properly protect every part of a building, it is necessary to employ a radial system of metallic conductors, which will enable the electricity concentrating in the earth from all directions to unite with that from the clouds by different paths about the building, thereby preventing an excessive flow of electricity over or through any portion of the building.

In Fig. 6 is shown the best radial system of metallic conductors for the protection of a building, consisting of an air-terminal conductor, G, upon the ridge at or near each end of the building, a metal roof and a rain-pipe, A, at or near each of the four corners of the building, metallically connected at *c* with a perforated iron pipe, C, leading into the earth in line with the gutter or drain, I. All the said conductors being electrically connected together, so that there will be four direct metallic paths from the lower end of each air-terminal conductor to the earth via the metal roof and the four rain-pipes. In order to more fully connect the air-terminal conductor, G, and the metal roof with the earth-terminal conductors, wire cables or stranded-wire conductors, D and D′, can be employed between them at or near each corner of the building, as shown.

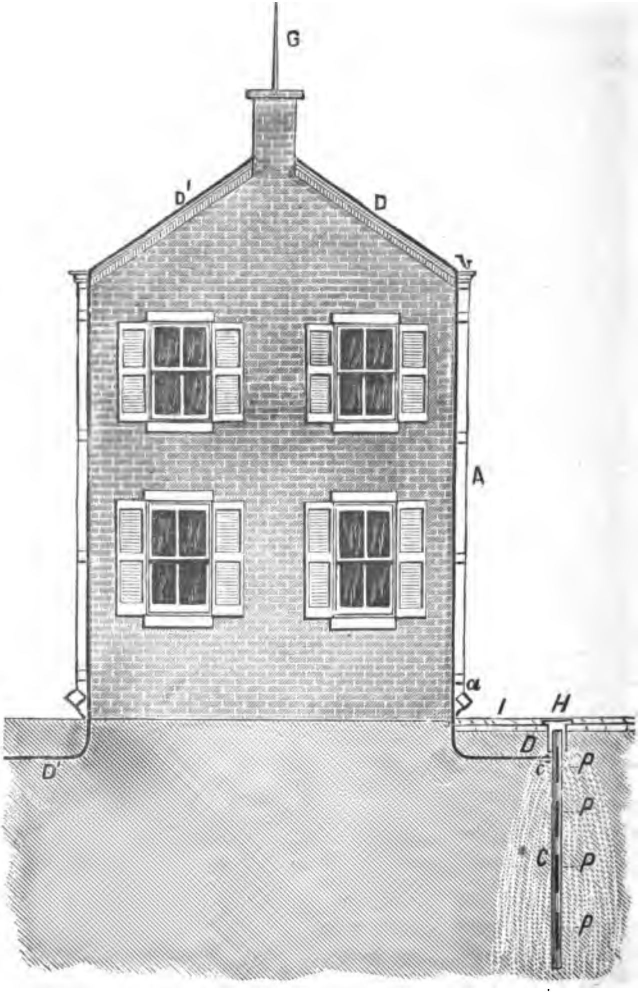

Fig. 6.

The Employment and Reliability of the Ordinary Rain-Pipes and a Metal Roof as Lightning-Conductors.

A IS a metallic rain-pipe of a cylindrical, corrugated, rectangular, or any other suitable form,—one which will prevent the joints from bursting during the winter season by water freezing therein being preferred. When used as lightning-conductors, rain-pipes should preferably be made of tinned or galvanized sheet-iron plates about thirty-six inches long, fourteen inches wide, and IXX brand, or No. 27 Wire Gauge in thickness. Those made of tinned iron plate twelve inches long, ten inches wide, and IC brand in thickness, will answer the purpose; but they are not as substantial and reliable as those made of longer, wider, and thicker plates.

The lengths or pieces of each rain-pipe must be tightly fitted together; and it is also advisable to solder each joint, in order to prevent any two of the lengths from separating and breaking the continuity between them.

The top of each rain-pipe must also be well connected and soldered to the tinned iron or other metal roof, at each gutter, *b*; and in case the building has metal troughs beneath the eaves of the metal roof, the tops of the rain-pipes must be soldered to the troughs, and a metallic connection made between the troughs and the metal roof by means of tin plates, IXX brand, fourteen inches wide, well soldered to the roof and each trough, and which should be arranged like sheet-metal band, G, in Figure 9, so that the centre of each plate will be about in line with the centre of the opening in the trough where it empties into the rain-pipe, and thereby effect direct and easy paths over the metal troughs between the metal roof and each rain-pipe.

The lower or elbow portion, *a*, of each rain-pipe should also be tightly fitted to its adjacent length; but in such sections of the country where the winter season is very cold it is not advisable to solder the joint, as the pipe, A, is apt to become filled with ice during very cold weather, and it is sometimes necessary to disconnect the lower portion, *a*, in order to remove the ice therefrom.

When two buildings of different height, having metal roofs, are adjacent to each other, it is advisable to metallically connect the said roofs together by means of a tinned or galvanized sheet-iron band, not less than ten inches wide, and No. 27 Wire Gauge in thickness, which should be placed so that the routes between the air-terminal conductors upon the roof of the higher building and the nearest rain-pipe, leading from the metal roof or trough of the lower building to the earth, will be as direct as possible.

A suitable rain-pipe, connected with and extending from the gutter of the metal roof of the higher building and emptying upon the metal roof of the lower building, can be used as the connecting conductor between the said metal roofs by soldering a plate, J, of tinned or galvanized sheet-iron, not less than ten inches wide, and No. 27 Wire Gauge in thickness, or two plates, each five inches wide, to the lower part of the elbow or lower portion, K, of the said rain-pipe and the metal roof, L, of the lower building, as shown in Figure 7, and thereby effect a proper electrical connection between them.

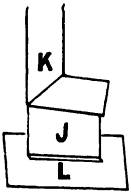

Fig. 7.

The elbow portion of a rain-pipe which extends from the eave of a building and empties upon the metal roof of a shed or portico, should be connected in a similar manner to the said metal roof, and the rain-pipe leading from the roof of the shed or portico is to be used as the connecting conductor with the earth.

As the electricity in a lightning discharge has a strong downward tendency towards the earth, and will not follow a very indirect route, it is advisable to locate the rain-pipes and their earth terminals so that the metallic paths between the air-terminal conductor upon the most elevated projection of the roof and at least two of the earth terminals will be in as short and direct routes as can conveniently be made; and in no case should the distance between any two rain-pipes exceed fifty feet.

A metal roof, and tin-plate, or galvanized sheet-iron, in the form of a pipe, band, or course, are really the most suitable metallic conductors by which absolute protection can be effected, as they are properly adapted for the great expansive action of the electricity in a lightning discharge.

When a lightning discharge passes through a solid rod $\frac{7}{16}$ inch in diameter, its expansive action is confined to a much smaller scope or space than when it passes through the same quantity of metal in the form of an ordinary tinned iron plate, or a hollow cylinder like a rain-pipe. In the case of the plate or rain-pipe, the electricity of great intensity can spread out and become electricity of lesser intensity.

It has generally been supposed that a metal roof and its rain-pipes were poor conductors of the electricity in a lightning discharge, owing to the thinness of the metal employed. They are, however, much better adapted for lightning protection, if well connected with the earth, than any other ordinary metallic conductors that can be employed. A rain-pipe four inches in diameter, or a band or course made of tin or terne plate, IXX brand, fourteen inches wide, has about the same quantity of metal per lineal foot as a round iron rod $\frac{9}{16}$ inch in diameter; and if its parts are well fitted or soldered together, it is fully three times better adapted as a lightning-conductor than the best copper conductor now erected, having much more capacity or scope for the expansive action of the electricity in a lightning discharge, and thereby able to greatly diminish its mechanical force.

That a metallic roof and its rain-pipes constitute a much better path for the electricity in lightning discharges than the metallic conductors heretofore employed, has been frequently demonstrated. On quite a number of occasions the ordinary lightning-conductors or rods erected upon buildings were struck at their air terminal or highest portions by lightning discharges; and at the points nearest to the metal roofs or rain-pipes the principal portion of the electricity left the regular conductors, and passed over to and down the metal roofs, rain-pipes, and rain-water flowing out of the lower ends to the earth, owing to the fact that the rain-pipes and the water flowing out of them furnished a better medium for the expansive action of the electricity, and an easier path to and from the earth than the regular lightning-conductors and the dry earth which surrounded their lower terminals. In a number of such cases the metal roofs and rain-pipes were partially melted at the points where the discharges entered and left them, and the pavement and earth beneath the outlet of the pipes were torn up. By properly connecting the rain-pipes with the earth, all liability of damage to the metal roofs, rain-pipes, building, and pavement will be prevented.

Quite a number of other instances can be cited, where buildings furnished with metallic coverings upon their roofs, which are connected by metal rain-pipes with ordinary iron drains imbedded for some distance in the earth, have escaped damage from lightning discharges. The iron drain-pipes emptying into sewers in many cities cannot, however, always be considered as reliable earth terminals, owing to the short distance and depth they usually extend through the earth, and the dry condition thereof during the summer season.

On the other hand, quite a number of buildings having metal roofs and rain-pipes have been damaged and destroyed by heavy electrical discharges, and the inmates injured and killed, owing to the rain-pipes not having been connected with the earth.

When a metal roof and its rain-pipes are disconnected, or not well connected with the earth, they are, to a certain extent, like many of the worthless lightning-conductors now erected. They will receive a heavy lightning discharge, but not having proper earth terminals or connections by which the electricity of the clouds and earth can readily unite, the building is liable to be destroyed or damaged, and the inmates killed or injured.

The Air-Terminal Conductors.

THE chimney of a building from which heated air and smoke escape, is more apt to be struck by a lightning discharge than any other elevated projection or part of a building. This is owing to the current of heated air and smoke forming, in connection with the soot in the chimney, a line of medium conductors leading to the stove-pipe and stove, heater, or range in the building, and thereby making an easier and shorter path to the earth than other portions of the building. It is therefore necessary that a suitable metallic conductor should be employed along and above each chimney, also other elevated projections upon the roof, in order to properly protect them, and prevent the electricity from entering the building. As chimneys and other ordinary projections upon the roofs of buildings do not offer a wide scope for the expansive action of the electricity in a lightning discharge, it is not necessary to employ broad metallic conductors to protect them, but wherever convenient they should be used.

A round iron rod, G, half an inch in diameter, is well adapted as an air-terminal conductor, when arranged as shown in Figure 6. It is substantial and not liable to be bent by the wind, which occurs with the wire cables and other forms of lightning-conductors now erected. It extends from the ridge of the metal roof about four feet above the top of the chimney, or other elevated projection, and is fastened thereto by iron staples. Its lower end should be well connected with a flat iron bar about 30 inches long, 1½ inches wide, and ⅛ inch thick, which should be bent like the bar, F, in Figure 10, and fitted over the ridge of the metal roof and soldered thereto, and thereby establish a good electrical connection between the rod, G, and the metal roof on both sides of the ridge.

A great deal of importance has been given to the manner of terminating the upper end of an air-terminal conductor. The prevalent opinion is that it should have one or more bright points, as suggested by Franklin in 1750. It is true, that when the electricity accumulated in a Leyden jar is discharged by means of a sharp point, there is not that snapping spark which occurs when a blunt end or ball is employed; but when we consider the great quantity of electricity accumulated in a thunder-cloud, and the great expansive action of a lightning discharge, it is quite evident that the electrical experiments made by Franklin with the Leyden jar, upon which the employment of points upon the upper end of a lightning-conductor is based, cannot be considered as legitimate illustrations for determining the necessary requirements for effecting protection from atmospheric electricity.

To improve its appearance, the upper end of an air-terminal rod can be pointed, but it need not be tipped with platinum, copper, or any other metal.

The electricity in a lightning discharge frequently passes through 3000 feet of air, which is the poorest conductor, to reach the earth; and it is therefore absurd to suppose that a small thickness of rust that may be formed upon the upper end or any other part of a lightning-conductor, will prevent the electricity from the clouds readily passing through it and over the conductor to the earth.

A chimney can also be properly protected by means of an ordinary galvanized sheet or cast iron cap thereon, which must be connected with the metal roof by a suitable flat iron bar, or preferably by a band of tinned or galvanized sheet-iron not less than nine inches wide, and No. 23 Wire Gauge in thickness; and when the chimney is in line with the ridge of the roof, the centre of the connecting band should be in line with the ridge of the metal roof.

When a chimney is located below the ridge or near the eave of the roof, it is advisable to employ a metal cap thereon, and connect it with the metal roof, in addition to employing the air-terminal rod, G, extending above the ridge. Metallic ventilators, cornices, iron railings, and all other metal masses upon the roof of a building or a projection thereof, must also be connected with the metal roof by a similar sheet-iron band, and thereby serve as air-terminal conductors, for which purpose it has been fully demonstrated they are much better adapted than all the polished points that can be employed. A platinum, copper, or other metal point is invariably melted by the electricity in a lightning discharge, while there is but little fusion of metal when a large metal mass is struck by a lightning discharge, and particularly when it is well connected with the earth, for the reason that a wide scope is given to the electricity, and its intensity is thereby greatly diminished.

A flagstaff upon the roof of a building should have a galvanized iron wire, about No. 6 Wire Gauge in thickness, attached thereto by iron staples, or be set in a groove in the pole, in order to prevent it being split into fragments by a lightning discharge. The upper end of the wire should extend about six inches above the top of the pole, and the lower end be soldered to the metal roof or other suitable conductor upon the roof.

It is advisable to so place the air-terminal conductors at such points along the ridge of the roof of a building as to be in as short lines as possible with the rain-pipes leading from the eaves of the roof to the earth; and where the distance between the rain-pipes or two chimneys, or other projections upon the roof of the building, exceeds forty feet, it is prudent to erect an intermediate air-terminal conductor extending above the ridge, and connect it with the metal roof or other suitable conductors leading in short lines with the nearest rain-pipes, and wherever convenient the distance between the air terminals should not exceed thirty feet.

An Improved and Reliable Earth Terminal.

SCIENTIFIC journals and writers on lightning-conductors have generally recommended that they be terminated in well-moist earth, but they have neglected to state that the surface earth adjacent to a building is, as a rule, kept rather dry, and particularly during the summer season.

Well-moist earth of a suitable area can only be found, during the summer season, in the immediate vicinity of springs, creeks, streams of water, and the subterranean water-bed. The depth of the water-bed below the surface of the earth can be ascertained by measuring the distance to the level of the water in the wells in the neighborhood.

Charcoal, coke, scraps of iron, and metallic ores have also been recommended and placed around the lower terminals of lightning-conductors, by which the area of good conducting material is increased in the earth; but owing to the small quantity of said material that can conveniently be used, and the dry condition of the earth around and beneath the charcoal, etc., a proper diffusion of the electricity in lightning discharges cannot be effected by the employment of said material.

The writer has given the subject of earth terminals for lightning-conductors considerable attention, and has overcome the difficulty that has heretofore been experienced in effecting the easy passage of the electricity in and over the earth, during a lightning discharge, by employing the waste and rain water in connection with the improved earth terminal, C, as shown in Fig. 6.

The improved earth terminal consists of a pipe not less than ten feet long, two inches inside diameter, and about one-quarter inch thick, made preferably of rolled iron in a single length, or two or more lengths, each about five feet long, with the usual opening at each end, and perforations or openings, P, along its length. The said perforations can be round holes, half an inch in diameter, or slotted openings, five inches long and one-quarter inch wide, and be placed at intervals of about ten inches from each other, preferably in two lines opposite each other.

The pipe can be round, square, triangular, or any other suitable form; and instead of employing a solid pipe with perforations, curved, flat, or angle bars of iron can be employed and be attached at both ends, also the centre, to suitable metallic devices, so there will be suitable spaces or openings between the bars, through which the water can pass and moisten the surrounding earth, and answer the same purpose as a solid perforated pipe.

A plate of rolled iron can be employed in the form of a pipe, with the longitudinal ends separated about a quarter of an inch, so that water can escape into the earth along its entire length, and also allow the pipe to expand when ice is formed therein.

The pipe, C, can be driven into clay, sand, and gravel soil in the same manner as the pipe of a driven well is placed in the earth. A metal shoe with sharp edge can be used at its lower end instead of the pointed device used with the driven well pipe, and the earth removed from the interior of the pipe by means of a common screw auger of suitable diameter, which can also be used for testing the ground before driving down the pipe, and thereby avoid striking large stones or solid rock.

Pipe C should be placed so that the waste water from a hydrant or pump in the vicinity of the building, and the rain-water from the pipe, A, flowing along the gutter or drain, I, will readily enter it through its top opening, and passing through its lower and side openings, cause a suitable area of earth around and beneath it to become and remain moist during the whole year, and thereby effect an easy electrical path between the lower end of the pipe, C, and the subterranean water-bed.

Wherever convenient, the pipe, C, should be located not less than eight feet from the foundation wall of the building, so as to allow a suitable area of earth to be moistened, and prevent the said wall becoming saturated with moisture. In cities and towns it can be placed near the curb line or in the street gutter, when employed in connection with the rain-pipe, or other lightning-conductor, along the front part of the building, and where the earth terminal must be placed within eight feet of the foundation wall of a building in order to be in line with the flowing waste and rain water along a gutter or drain, it is necessary to employ a solid pipe without perforations between the surface of the earth and a point about two feet below the surface of the cellar of the building, and a perforated pipe not less than six feet long below the solid pipe, and thereby maintain a suitable area of moist earth below the surface of the cellar and without saturating the foundation wall or walls of the building with moisture.

Pipe C should, preferably, be set in the earth so that its upper end will be about six inches below the surface of the earth, so as not to be exposed to the rays of the sun and become greatly heated during the summer season, and thereby prevent the moist earth around its upper end being soon dried up. A suitable pipe, H, about four inches inside diameter and eight inches in length, can be placed around the upper end of pipe, C, but not in contact with it. Its upper end should be nearly flush with the gutter or drain, I, or the surface of the earth, and contain a perforated screen, which will allow the water to flow readily into pipe C and around its top, but prevent the passage of trash therein, with which it might otherwise become filled.

The top of pipe C can be set nearly flush with the gutter, I, and be covered with a suitable screen, and thereby dispense with the pipe, H, where the pipe, C, is not exposed to the sun or is required to be placed near the foundation wall of a building.

In large cities the rain-pipes upon buildings generally connect with and empty into iron drain-pipes leading into sewers, which cannot be considered as reliable earth terminals, owing to the short depth they usually extend through the earth and its dry condition during the summer season. In such cases it will be necessary to place a perforated pipe not less than six feet long in the earth, with its top about two feet beneath the surface of a cellar, vault, or any other suitable place convenient to the drain-pipe, and be supplied with water therefrom by means of an iron pipe about two inches outside diameter, which must be properly connected with the drain-pipe, and tightly fit into the top portion of the perforated pipe, so that the water will readily flow from the drain-pipe into the perforated pipe, and at the same time prevent the surface portion of the cellar or vault becoming saturated with water, as it is not desirable to have it in a very damp or moist condition.

During the beginning of a thunder-storm, the water from rain-pipe A, flowing along the gutter I, will soon fill the pipes C and H, and flow in a body over them, and establish an electrical connection between the top of pipe, C, and the moist surface earth, which, together with the moist earth around and beneath the pipe C, will constitute easy paths for the electricity of the clouds and earth, while quickly uniting. Solid rock greatly impedes the electricity of a lightning discharge in its passage over the surface earth to or from the subterranean water-bed, and to drill a hole in the rock so that an earth terminal can reach the water-bed is rather expensive. The liability of damage to a building erected over a stratum of solid rock can be greatly lessened by providing it with a metal roof and connecting its rain-pipes with earth terminals of suitable forms, each having not less than twenty square feet of surface, which should be placed vertically in the earth, as deep as possible, and with the top portions contacting with the rain-water flowing along the gutters.

Several other devices and methods have been tried for moistening the earth around a metallic terminal, but they have been found to be unreliable, owing to the small area and short depth of earth made moist.

The perforated iron pipe, arranged as described, is the only unobjectionable and reliable method by which the waste and rain water can be made use of for maintaining a suitable area of moist earth, and effecting an easy route for the passage of the electricity in the earth.

It enables the rain-water during a thunder-storm to spread out over a large area of earth and to a considerable depth *in a short space of time*, which is a very important feature. It also enables the waste water to enter the earth at a depth where it is not so compact as at or near the surface, and where it is not dried up by the heat of the sun, thereby constantly maintaining a line of moist earth extending towards the subterranean water-bed.

It is the only arrangement by which the rain-water flowing along a gutter and over the surface earth, during a storm, can conveniently be used to diffuse a considerable portion of the electricity in a lightning discharge.

Connecting Conductors between the Rain-pipes and Earth Terminals.

A METALLIC connection must be made between the rain-pipe, A, and the perforated pipe, C, by means of a suitable metallic conductor, J, which can consist of a flat iron bar not less than two inches wide and one-eighth inch thick, and be bent as shown. The vertical portion should be placed with its wide part parallel with the wall of the building, and, if necessary, be fastened thereto by a suitable staple or other device, and the horizontal portion should be imbedded in the earth to the depth of about ten inches.

The upper portion of bar, J, should be placed behind the rain-pipe, A, and extend about eight inches above the top of the elbow portion, *a*.

To the length of rain-pipe, A, above the elbow portion, *a*, a suitable galvanized iron socket or slip joint device, E, about six inches in length, is connected, as shown in Figure 8, preferably by soldering. Into the opening thereof, the upper end of flat bar, J, is inserted about five inches, and fits snugly therein, so as to form a good electrical connection between them. To the lower side of the elbow portion, *a*, of the rain-pipe, A, the curved conductor, F, is soldered, which is connected to flat bar, J, by one or more screws or other suitable devices. The object of the two connecting devices, E and F, is to effect an easy passage of electricity between the rain-pipe and the connecting conductor, J; and should it be necessary to remove the lower or elbow portion, *a*, the continuity between the rain-pipe, A, and the conductor, J, will be maintained by device E.

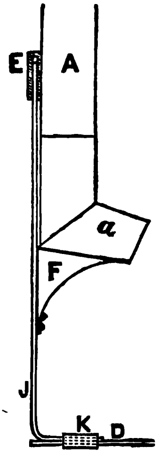

Fig. 8.

The bar or conductor, J, can be connected directly with the perforated pipe, C, or through conductor, D, by means of a sleeve or suitable device, K, beneath the pavement, as shown in Fig. 8. The conductor, D, being joined in a similar manner to the iron arm or projection, *c*, of perforated pipe, C, as shown in Fig. 6.

Should the building have gas- and water-pipes, the conductor, D, or bar, J, must also be connected with the said pipes near the foundation wall of the building, either inside or outside the cellar, by means of a wire cable or other flexible conductor, having not less than .40 of a pound per lineal foot, thereby safely restoring the disturbed electrical equilibrium of the building, and preventing lateral discharges between the said rain-pipe and connecting conductors, and the gas- and water-pipes.

Some of the gas corporations have objected to connecting lightning-conductors with the pipes leading to the gas-mains, and making use of them as earth terminals. They should, however, bear in mind that the electricity of the clouds and earth have, by their inductive influence, an affinity for the gas-mains; and if the nearest rain-pipe or other lightning-conductor is not connected with the pipe leading to the gas-main, near where it passes through the foundation wall of a building, a lightning discharge itself is nevertheless disposed, and may be able, to reach the gas-main by passing through the wall to the nearest gas-pipe inside the building, melting the lead joints of the meter and setting the escaping gas on fire.

Gas- and water-mains are generally imbedded in the earth to the depth of about four and a half feet, and during the summer season the earth around them is kept in a rather dry condition, which has caused lightning discharges upon a number of occasions to melt the lead packing at the joints of the street-mains, and caused the gas and water to escape. The perforated iron pipe, C, in connection with the moist earth and flowing rain-water, during a storm, is better able to diminish the intensity of a lightning discharge than the gas- and water-pipes and mains in the vicinity of a building; and when a connection is made between the perforated pipe, C, or rather its connecting conductor, D, and the gas- and water-pipes, as recommended, the lead packing at the joints of the gas- and water-mains will be prevented from being melted by a heavy lightning discharge.

Protection of Wooden, Slate, Gravel, and Mansard Roofs, Steeples, etc.

In the application of lightning-conductors to wooden, slate, gravel, and other roofs, it has been customary to place them upon the outside, along the ridges and down one or both ends or sides of the buildings, and also along other parts of the roofs, so that the routes between the air-terminals and the vertical portions of the conductors leading from the eaves or ends of the buildings to the earth are long and indirect, and thereby jeopardize the roofs, as the electricity of the air and earth usually unite above a roof and will not follow a metallic conductor or path upon a roof when it is in a long and indirect route. Many of the lightning-conductors now erected are in very indirect routes upon the roofs of buildings, as shown in Fig. 16, and consequently will not effect proper protection.

The application of metallic conductors upon the outside of wooden, slate, gravel, and Mansard roofs, steeples, and other elevated projections, and particularly in short and direct lines, is objectionable, as the roofs, etc., are disfigured by the conductors, and in attaching their fastenings to the roofs, the slate is broken and shingles or wood-work split, so as to allow the water to enter the interior of the buildings during a storm or from melting snow upon the roofs.

Lightning-conductors placed upon the outside of slate roofs are also apt to be torn from their fastenings and carried to the ground by the large quantity of snow which generally accumulates and presses against them during the winter season.

In order to effectually prevent wooden, slate, and other roofs, steeples, towers, observatories, skylights, and other elevated projections above the roofs, from being damaged by lightning discharges, and also disfigured and damaged in applying lightning-conductors thereto, it is necessary to employ bands of tin plate or galvanized sheet-iron, having the same quantity of metal per lineal foot as the rain-pipes extending from the eaves of the roofs to the earth, and place them in as short and direct lines as possible beneath the slate covering or wooden laths or rafters of the roof, etc., between the air-terminal conductors and the said rain-pipes or other suitable vertical conductors. The said bands and rain-pipes should, preferably, be made of tinned or galvanized iron plates, about 36 inches long, 14 inches wide, IXX brand or No. 27 Wire Gauge in thickness. In Fig. 9 is shown an arrangement of metallic conductors upon one side of a slate, wooden, or gravel roof

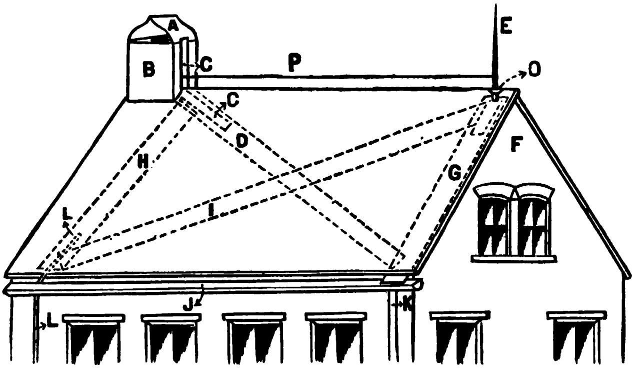

Fig. 9.

of a building, not exceeding thirty feet in length or width, by which proper protection will be effected. A is a cast or galvanized sheet-iron cap or ventilator upon the top of chimney, B, at one end of the roof, and serves as an air-terminal conductor. E is a round iron rod about five feet long, and serves as the air-terminal conductor at the other end of the roof. J is an ordinary metallic trough beneath the eave of the roof, and to which the metallic rain-pipe, K, which must not be less than three inches in diameter, is well soldered. D, G, H, and I are sheet-metal bands, the plates of which are of the same width and thickness as those employed in the rain-pipe, K, and are placed beneath the wooden rafters or laths on each side of the roof, in as short and direct lines as possible, between the chimney-cap, A, air-terminal rod, E, rain-pipe, K, and wire cable or other suitable conductor, L, as shown, and are well soldered or fastened to each other, thereby providing two direct metallic paths from chimney-cap, A, and rod, E, to the earth, on each side of the roof and building to the earth.

The air-terminal conductors, A and E, are connected together by a wire cable or other suitable conductor, P, which can be placed about six inches or more above the ridge of the roof by means of suitable iron supports. The air-terminal conductors, connected together and with the earth as described, will cause the electricity of the air and earth, while in the act of uniting, to greatly spread out above the top of the building, and also give it a wide scope in its passage about the building.

The band, G, and rain-pipe, K, can be connected directly with each other or soldered to trough, J, as shown. A suitable wire cable can also be employed, same as cable, L, between band, G, and its earth-terminal, in addition to rain-pipe, K. Chimney-cap or ventilator, A, is connected with band, D, by a tinned or galvanized sheet-iron band, C, nine inches wide, and about No. 23 Wire Gauge in thickness, or by any other suitable conductor.

The arrangement of the lower end of air-terminal rod, E, and its connection with band, G, is fully shown in Fig. 10. It passes through a suitable hole in the centre of rafter, L, or a ridge pole or suitable piece of wood placed between two rafters, and is screwed into or well connected by a nut, *e*, to tinned or galvanized flat iron bar, F, which is not less than 24 inches long, 1½ inches wide, and ⅛ inch thick, and bent in the centre as shown, and fastened to rafters, L and L′, with nails, screws or staples, thereby maintaining rod, E, in a proper vertical position without requiring a standard or upright above the roof to support it, as is the case with the spiral-twisted, wire cables and other forms of air-terminal conductors now erected. The sheet-iron band, G, is placed between bar, F, and rafter, L, and by soldering it to the said bar, a good electrical connection will be maintained between them. In order to prevent the water flowing down the rod, E, from entering the interior of the roof during a storm, it is necessary to fit a suitable tin plate, O, with a hole in its centre, around the said rod and be soldered thereto, above the wooden sheathing or other covering M, M′, of the roof. The sheet-metal band, G′, connects bar, F, with the metallic trough, rain-pipe, or other suitable vertical conductor on the other side of the building.

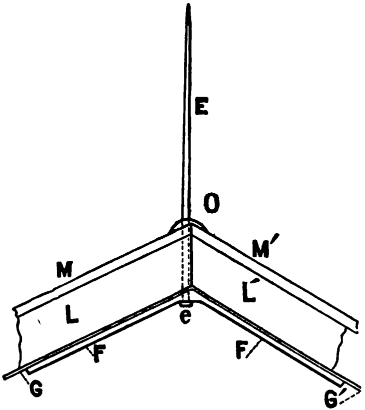

Fig. 10.

In Fig. 11 is shown a cottage having a small extension, R, the roof of the main building and that of the extension being covered with slate, except at the sheet-metal valleys, L, between the two roofs. To the chimney, B, in the centre of the main roof, the air-terminal rod, A, is applied, which is connected by horizontal conductor, P, with the air-terminals, C and D, at the opposite ends of the said roof. The sheet-metal bands, F, G, H, I, and J, are placed beneath the slate, upon the felt or paper covering, and fastened to the top of the wooden sheathing of the roof by nails, and are soldered to each other and also to the metal gutters or troughs, M and N, and top of the two metal valleys, L, between the roof of the extension, R, and the main roof as shown, thereby providing two short paths from each air-terminal conductor to the earth, via the rain-pipes or other suitable vertical conductors, O and Q.

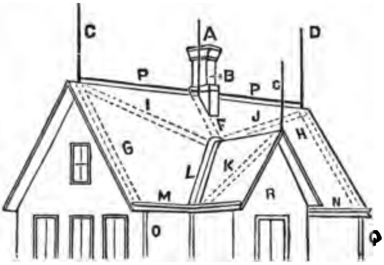

Fig. 11.

The connections between the air-terminal conductors, C, A, and D, and sheet-metal bands, G, F, and H, are made by flat iron bars, similar to bar, F, in Fig. 10, which is set into the top of the wooden sheathing and fastened thereto by screws, so that its top is flush with the top of said sheathing. The said bands being placed beneath the said bars and soldered thereto.

The roof of the extension, R, is protected by means of the air-terminal rod, c, placed at the end of the said roof and connected with metal gutters or troughs, M and N, or with the lower part of the metal valleys, L, by means of a sheet-metal band, K, placed beneath the slate on each side of the roof of the said extension in a short and direct line as shown.

In the case of a Mansard roof, the rain-pipes, sheet-metal conductors along the angle beads or corners, also any metal valleys or flushings can be used as the connecting conductors, or parts thereof, between the metal covering upon the deck roof and the metallic gutters above the house cornices, provided they are in direct lines with the rain-pipes leading from the cornices to the earth, and the plates thereof are not less than ten inches wide; and where they are not in direct lines with the said rain-pipes, it will be necessary to employ suitable sheet-metal bands beneath the slate covering or wooden sheathing between the deck roof and the cornice gutters.

A high steeple upon a church or other building, should have a suitable metallic ornament at its top, which can serve as an air-terminal conductor, and answer the purpose much better than a pointed rod. A substantial iron rod, not less than an inch in diameter, should be well connected to the said ornament, and extend not less than ten feet into the interior of the steeple, and be well secured in order to hold the ornament in its position. To the lower end of said rod, a flat iron bar, like bar, F, in Fig. 10, should be well connected at its centre, with the ends thereof bent downward, to which two metallic bands, preferably about 14 inches wide and No. 27 Wire Gauge in thickness, should be soldered thereto for about twelve inches. They should extend along the inner sides of the steeple, and be connected with the metal roof of the building at or near the base of the steeple, or, in case of a wooden or slate roof, the bands should be extended in a line with the nearest rain-pipes on each side of the building, and be soldered to the metallic gutters or troughs at the eaves of the roof.

It is also advisable to place suitable metallic ornaments, or other conductors, around the steeple at intervals of about every twenty feet, between its top and base, and connect them with the vertical connecting bands upon the interior of the steeple, and thereby intercept any lightning discharge which might take place in line with the centre or any other portion of the steeple beneath its top, and carry it safely to the earth.

Some years ago, Ganot, a French scientist, reported to the French Academy of Science that a lightning-conductor, or its air-terminal portion, would protect a circular space the radius of which is equal to twice its height above the ground or above the roof of a building. This rule cannot always be relied upon, for the reason that a discharge is sometimes deflected from the path that it would ordinarily take in line with the highest projecting point of a building by the rain, when it is driven in a certain direction by the wind, also by other circumstances. Lightning discharges have been conveyed by the falling rain in line with the bases of steeples and roofs of churches, at the same time with the tops of the steeples. It is therefore advisable to employ intermediate air-terminal conductors along a steeple, and also at intervals of about twenty-five feet along the ridge of the roof of a church. Instead of employing iron rods, suitable metal ornaments about two feet high can be employed as the air-terminal conductors along the ridges of the roofs of churches and other large buildings.

A suitable air-terminal conductor should be placed upon the top of an observatory or tower, and a suitable number of air-terminal conductors upon the top of a long skylight, at intervals of about twenty-five feet, and be connected with the main metal roofs, or the metallic gutters or troughs at the eaves of the roofs, by two suitable sheet-metal bands extending from each air-terminal conductor, and placed in direct lines with the nearest rain-pipes on both sides of the building.

The connecting sheet-metal bands employed between the air-terminal conductors or metal coverings upon Mansard and other roofs, and the rain-pipes leading from the eaves of buildings to the earth, should be fastened to the wood-work upon the interior of the roofs, steeples, observatories, etc., by means of nails, and need not be insulated therefrom.

If the said rain-pipes are well connected with the earth, there is no liability whatever of the wood-work, or other material about a roof, steeple, etc., being set on fire or damaged, or any person beneath the roof or inside a steeple being injured by the electricity in a lightning discharge while passing over the said metal bands.

Employment of Gas, Water, and other inside Pipes, etc., as Additional Lightning-Conductors.

DURING a thunder-storm, the gas, water, heating, and ventilating pipes, and other vertical metallic conductors upon the inside of a building which extend to or near the roof thereof, become highly electrified by the inductive influence of the electricity in the cloud above, and are apt to be selected as part of the path for the passage of the electricity in a heavy lightning discharge, the expansive action thereof being sometimes so great as to cause it to fork into a number of branches as it approaches or reaches the roof of the building.

In their normal state, the said pipes and inside metallic conductors are, to a certain extent, a source of danger, during a storm, to a building and its inmates; but by properly connecting them with the metallic roof or air-terminal conductors upon the roof, or with the connecting bands between the air-terminal conductors and the rain-pipes, and also connecting them together in the cellar, and with a perforated iron pipe placed upon the outside of the building, by means of wire cables or other flexible conductors, having not less than .40 of a pound per lineal foot, they become the means for effecting the proper protection of the building, as they will greatly diminish the intensity of a lightning discharge and safely restore the disturbed electrical equilibrium of the building.

The larger the number of vertical metallic paths or conductors employed from the roof of a building to the earth, also earth terminals, the more readily will the intensity of a lightning discharge be diminished, and the greater will be the protection to the building and its inmates. Should the continuity of the rain-pipes or other metallic conductors upon the outside of the building become broken by accident or otherwise, the inside pipes or other metallic conductors will be able to properly protect the building.

A good electrical connection is always maintained at the joints of gas-pipes, for the electricity in a lightning discharge, by the iron screw threads thereof contacting with each other. If the gas-pipe which leads from the meter to the street main is connected with a perforated iron pipe, as recommended, and the iron pipes leading to and from the meter are connected together by means of a sheet-metal band, six inches wide, and No. 20 Wire Gauge in thickness, or any other suitable conductor, so as to shunt the meter, there is no danger of great heat being generated at any joints of the meter, house pipes or street mains, and the melting of the lead at the joints and escape of gas will be prevented.

A building over one hundred feet square cannot be properly protected unless, in addition to the rain-pipes or other conductors and earth terminals upon the outside thereof, a suitable number of conductors are employed through the interior, at intervals of not less than fifty feet, and are well connected with suitable earth terminals placed not less than ten feet deep in the earth in the basement or ground floor of the building, so that as short and direct paths as possible will be provided to the earth for lightning discharges taking place in line with the central portions of the roof.

The employment of lightning-conductors through the interior of a building has been recommended by the eminent electrician Faraday, and others, in order to secure direct and easy paths to the earth for a lightning discharge. That uninsulated lightning-conductors, provided with good earth terminals or connections, can be safely employed through the interior of buildings, is evident, when we reflect that they have been safely employed during the past fifty-five years through the interior of the hulls of ships.

Lightning discharges have frequently struck the telegraph wires in the vicinity of telegraph offices, and where the office wires were provided with a good lightning protector, well connected with the earth, the electricity has passed through the offices without causing any damage to the telegraph instruments or injury to the operators.

That large metallic conductors well connected with the earth will disarm the electricity in a lightning discharge of its destructive energy, and prevent injury to persons, even when in close proximity thereto, was fully demonstrated on the evening of the 12th of April, 1877, when the Carysfort Reef lighthouse, near Key Largo, Florida, was struck seventeen times within thirty minutes by heavy lightning discharges, the thunder thereof being of the most terrific character. This lighthouse is built in the water, on a submerged reef, and consists of a framing of stout iron pillars or piles, each about one hundred feet in length, arranged in the form of an octagon, with one pillar in the centre, interlaced at various points with smaller iron rods. At about forty feet above the water is the keeper's apartment, the roof and sides of which are of iron plate, while the floor is of wood.

During the storm several men were in the lighthouse, in close proximity to the metallic conductors surrounding them, over which the electricity passed to the water, but none were injured.

Protection of Barns, etc.

BARNS, when filled with new hay or grain, especially when it is not properly cured or dried, also buildings in which ice or other material is largely stored, are particularly liable to be struck and destroyed by lightning discharges, even when provided with the ordinary lightning-conductors, owing to the wide scope offered to the electricity of the air and earth by the large and compact masses of hay, ice, etc.

It is claimed that grass, when growing in the field, is covered with many minute organisms or germs, which, in the course of their growth, consume oxygen, and give off carbonic acid in great quantities, and derive their nutriment from substances of vegetable origin. When hay is not properly dried, these germs are not killed, but continue to grow, and in throwing off millions of offshoots they prey upon the grass, drink the water, and breathe the oxygen, which, however closely packed the hay may be, penetrates to the innermost recesses of the mow or stack. In doing all this, carbonic acid is produced, which, uniting with the oxygen, causes a great heat to be produced. When the heat produced by the germs has no means of escape, a temperature is reached at which the woody fibre of the hay and oxygen can combine, and ignition takes place.

The large mass of heated hay offers a much wider scope and better passage for the electricity in a lightning discharge than that offered by the ordinary lightning-conductor or conductors heretofore applied to barns. The result has been that many large barns, with their valuable contents, have been destroyed by the electricity leaving the ordinary conductors for the hay, and will continue to be destroyed until a radial system of metallic conductors is employed which will offer a better scope and easier path to and from the earth for the electricity in lightning discharges than the scope and path offered by the hay, or other material contained in the building. A metal roof, with two or three suitable air-terminal conductors attached thereto, and connected with at least four perforated iron pipes placed in the earth at or near each corner of the building by means of rain-pipes four inches in diameter, will effectually protect a barn, ice-house, or other structure used for storage purposes.

A barn having a wooden roof can be properly protected by employing three air-terminal conductors, C, C^1, C^2, connected together by wire cable or rod conductor, P, and also with two perforated iron pipes or earth-terminals, O and N, one at each corner, front and rear of barn, by means of wire cables, F, G, H, I, J, K, and L, placed on the outside of the roof and building as shown in Fig. 12, front and rear, thereby providing four short metallic paths from each air-terminal conductor to the four earth-terminals, one near each corner of the barn. The perforated iron pipes, O and N, should be so located that the water from trough, E, through its connecting rain-pipes, will flow in and over them, as fully shown in Fig. 6.

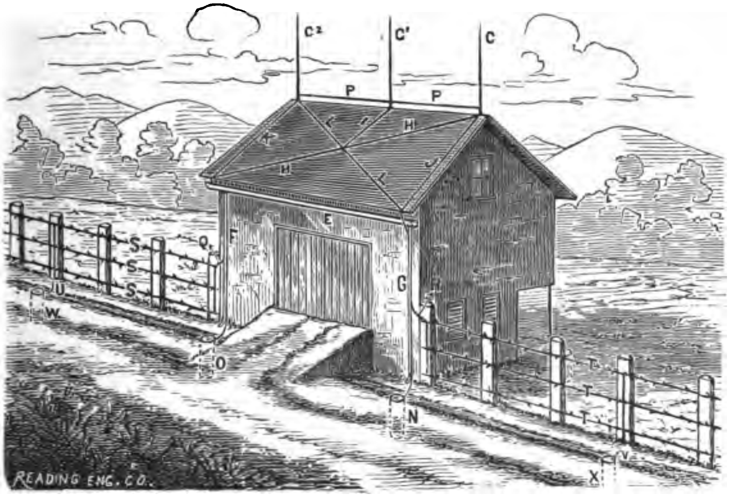

Fig. 12.

The barbed or plain fence wires, S and T, can also be used to facilitate the passage of the electricity from or to the earth during a lightning discharge, by connecting them with vertical conductors, F and G, by wires, cables, or other suitable conductors, Q and R, and also with the perforated iron pipes or earth-terminals, W and X, by wires, cables, or other suitable conductors, U and V.

Two earth-terminals can be employed in connection with each set of fence wires, S and T, placed at intervals of about sixty feet apart and from the barn. By employing long iron posts, placed in the earth for a depth of about ten feet at said intervals, in place of the wooden posts, the wires, U, V, and earth-terminals, W, X, could be dispensed with, as the said iron posts would then answer as earth-terminals.

In Fig. 13 is shown an arrangement of metallic conductors for the protection of a barn having a slate roof and ventilators, A A′, with openings, B B′, upon two sides thereof, through which the heat generated by the hay can escape from the barn.

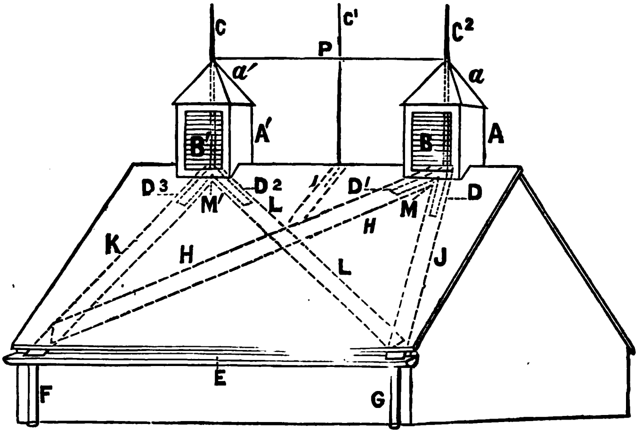

Fig. 13.

C, C¹, and C², are round iron rods, half an inch in diameter, extending into the interior of the ventilators as shown, and not less than three feet above the tops of the roofs, *a* and *a′*, thereof, and are connected together by wire cable or other suitable conductor, P.

The lower ends of the said rods pass through holes, M M′, in the centre of two flat iron bars, D D^1 and D^2 D^3, and are firmly held by a nut arranged like nut *e* in Fig. 10. The said bars, which are about one and a half inches wide, one-eighth inch thick, and of suitable length, should be bent like bar, F, in Fig. 10, and arranged at angles to each other, as shown in Fig. 14. The ends of said bars are fastened to the rafters of the wooden sheathing by screws or other suitable devices. Where there are no ventilators, the rods, C, C^1, and C^2, and bars, D D^1 and D^2, D^3 must be applied to the ridges of the roofs somewhat similar to the arrangement shown in Fig. 10. The air-terminal rods, C, C^1, and C^2, bars D D^1, D^2, and D^3, sheet-metal bands, H, I, J, K, and L, metal trough or gutter, E, and rain-pipes, F and G, are all electrically connected, thereby providing, as in Fig. 12, four short metallic paths from each air-terminal conductor to four earth-terminals, one near each corner of the barn.

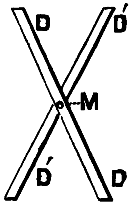

Fig. 14.

Wire cables can be employed between sheet-metal bands, J and K, and the earth-terminals, on each side of the barn, in addition to the rain-pipes, F and G.

Lightning-Conductors should not be Insulated from Buildings.

During a thunder-storm, the brick, wood, and other material about a building, become oppositely electrified by the inductive influence of the electricity in the cloud above it, although not so intensely as the metal roof, pipes, etc., thereof. In addition to furnishing a path for electrical discharges between the clouds and earth, it is also necessary for lightning-conductors to be arranged so as to effect the restoration of the disturbed electrical equilibrium of the building, without causing any damage to the building or stunning its inmates. This can be best accomplished by placing the conductors against the chimneys, or other elevated projections, roof, and walls of the building, and not separating and insulating them therefrom by means of glass or other insulators, as has been customary.

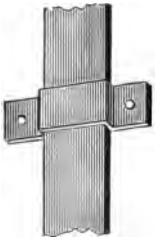

Fig. 15.

The conductors should be fastened to the buildings by means of iron staples, or straps of sheet-iron, bent as shown in Fig. 15, to conform with the conductor, and be pierced with two holes so it can be fastened to any part of a structure by screws or nails.

The practice of separating lightning-conductors from buildings, etc., by glass, horn, or other insulators, is not only useless but dangerous, as the disturbed electrical equilibrium of the building is thereby prevented from being safely restored. It is a prevalent opinion that, by thus insulating a lightning-conductor, a discharge will be prevented from entering the building. Nothing, however, is more ridiculous than to imagine that the electricity of a lightning discharge, which can break through a long distance of air and shiver into fragments the most compact bodies, would be arrested in its course by a few inches of insulating substance or a few feet of air.

As the metallic chimney-caps, metal roof, rain, gas, water, ventilating, and heating pipes are in contact with the different parts of a building, they will, when metallically connected together and employed as lightning-conductors, as hereinbefore described, enable the disturbed electrical equilibrium of the whole building to be readily restored, at the time of a lightning discharge, without causing any damage to the building or injury to its inmates.

The quantity of electricity contained in a lightning discharge between the clouds and the earth is very great, and, owing to its great expansive action, a portion thereof will invariably flow over the material of the building and its metal pipes, etc.; and if the metal pipes and large or long metal masses about the building are disconnected from the radial system of lightning-conductors hereinbefore described, the quantity of electricity flowing between the air-terminal conductors and the said pipes or masses may be sufficient to damage the intervening wood, brick, or other material of poor conductivity about the building, or injure the inmates of the building.

The greater the number of metallic paths from the top of the building to the earth, the smaller will be the quantity of electricity passing over the wood, brick, and stone of the building, which are safe conductors of a limited quantity of the electricity contained in a lightning discharge.

Defects of the Lightning-Conductors now Erected.

In determining the requirements of lightning-conductors, the manufacturers and erectors have, erroneously, been governed by the action and properties of galvanic and ordinary frictional electricity, and have neglected to thoroughly investigate the large area, action, and properties of the electricity of the atmosphere and earth, and the great quantity contained in the lightning discharges which take place between them. The result is, many of the lightning-conductors now erected have no less than four serious defects, and consequently will not properly protect the buildings to which they are attached.

Galvanic electricity has a medium quantity—the term used for indicating the amount of electricity present—and a low potential or tension—the term employed for indicating the property or function of electricity which determines its motion from one point to another. In the electricity generated by ordinary friction, the quantity is small and the potential high, while the electricity of the air and earth when in motion, as in a zigzag or rather spiral lightning discharge, combines great quantity with a very high potential, and is capable of producing effects which cannot be obtained by galvanic or ordinary frictional or induced electricity.

An artificial electrical discharge, produced by a Ruhmkorff coil or Holtz machine, can barely pass through two feet of air or several inches of glass, while a lightning discharge can readily pass through two miles of air and twenty feet of solid rock.

The round iron rods, wire cables, spiral twisted, and other forms of lightning-conductors now erected are too concentrated, and as applied to buildings will not allow the electricity in a lightning discharge to have a proper scope for its great expansive action, and consequently it will not confine itself to the said conductors, but will leave them for the buildings and their contents, to which they are attached.

A single lightning-conductor as now applied to a building will, if it contains a suitable quantity of metal and is well connected with the earth, protect that portion of the building to which it is applied, but not the whole building, owing to the great expansive action of the electricity from the clouds and the concentrative and upward action of the electricity of the earth, hereinbefore explained.

No building can be properly protected without applying a conductor to each of the four corners thereof, and employing the four vertical conductors in a radial system, as hereinbefore described.

Most of the lightning-conductors now erected contain a rather small quantity of metal, and are not able to properly resist the heating effect of the electricity in a heavy lightning discharge.

The weight of the wire cable, spiral twisted, and other peculiar and unscientifically formed conductors, varies from .16 to .48 of a pound per lineal foot, and the conductivity of most of them to the electricity in a lightning discharge is about equal to that of a round iron rod $\frac{5}{16}$ inch in diameter, which is not sufficient for safely conveying a very heavy charge of electricity, and fully resisting its heating effect. The quantity of metal should not be less than that contained in a round iron rod $\frac{7}{16}$ inch in diameter, which weighs .50 of a pound per lineal foot.

As the wire employed in an ordinary electric arc light circuit must not be less than No. 5 Wire Gauge in thickness, it is quite evident that the quantity of metal employed in the lightning conductors now erected is entirely too small, as the latter are subject to currents of electricity of much greater intensity than those generated by a dynamo-electric machine.

The electricity of the clouds and earth have a very strong tendency toward each other, particularly when in close proximity to each other while uniting in a lightning discharge, and will not follow a metallic conductor or path when it is an indirect route about a building.

The arrangement of conductors shown by the heavy lines along the ridges, gables, and eaves of the roof of building in Fig. 16 is defective, and will not afford proper protection to the roof. It is recommended by Prof. John Phin, in his work on Lightning-Rods, and is an illustration of the ignorance heretofore shown by scientists on the subject of lightning protection.

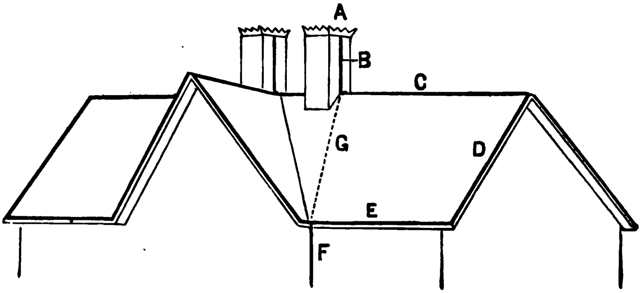

Fig. 16.

A lightning discharge taking place in line with the pointed metallic coping, A, upon the top of the right-hand chimney, is expected to follow the indirect route *via* the metallic conductors C, D, and E along the ridge, gable, and eave of the roof between the chimney conductor B and the vertical conductor F, which leads from the eave of the roof to the earth, while really it will take the more direct route, shown by the dotted line G, over the wooden rafters and sheathing of the roof between the conductors named. A large iron ball projected from a cannon with great force, might as well be expected to take such an indirect route.

The routes of many of the lightning-conductors now erected are very indirect, and particularly along the roofs of buildings, and consequently they will not effect safe passages for the electricity in lightning discharges.

In addition to the improper construction and application of lightning-conductors to buildings, they have not been placed in the earth to a suitable depth, thereby preventing the electricity from the clouds from readily uniting with the electricity of the earth, which is principally accumulated in the subterranean water-bed and not in the surface earth, as has been generally supposed. Many of the conductors now erected terminate in the earth from two to seven feet, alongside the foundation walls of buildings, as shown in Fig. 17, and have, on an average, a metal surface of only eight inches square in contact with the earth.

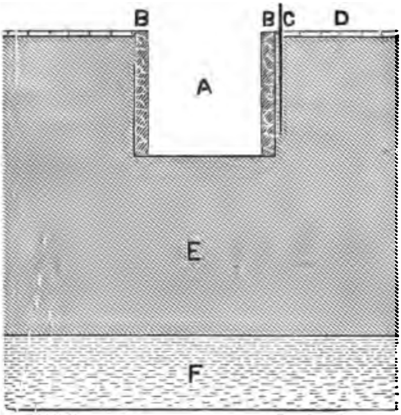

Fig. 17.

It has generally been supposed that at the depth of about six feet the earth adjacent to a building is in a moist condition during the summer season; but such is not the case. Rain is generally prevented by the building from falling near the foundation walls, and by the pavement, D, from penetrating the earth to a suitable depth; and, owing to the long intervals of rain and the excessive heat of the sun, the small quantity of rain that may have entered the earth near the lightning-conductor, C, during a summer-shower is soon afterward dried up. The earth, E, beneath the cellar, A, and pavement, D, is kept in a rather dry condition for a considerable depth, which, together with the poor conductivity of the stone wall, B, greatly impedes the passage of the electricity in a lightning discharge between the conductor, C, and the subterranean water-bed or permanent moisture, F, or vice versa.

If a river is dammed or cut off from shore to shore, except a single passage about a foot wide, there will naturally be a great obstruction to the current thereof; a great accumulation of water will take place, which can only find a suitable outlet to the water below the dam by overflowing the adjacent territory or violently breaking away the dam. A similar but more violent effect takes place when the electricity from a cloud alights upon a metallic or lightning-conductor, the lower end of which is disconnected from the earth or is separated from the subterranean water-bed or permanent moisture by dry earth or solid rock. The said electricity being greatly retarded in its passage, is compelled to seek some other outlet, and it invariably leaves the metallic conductor above the surface earth, and spreads out over the building and its contents in order to readily unite with the electricity of the earth. In a number of instances the electricity has also left the lower end of the lightning-conductor, C, and passed through the foundation wall, B, into the cellar, A, and over some of its contents.

It has been asserted by some scientists that water and moist earth are poor conductors of the electricity in a lightning discharge. Their opinion is based upon the comparative amount of resistance that is offered by water and metals to a galvanic current, which is electricity of a low potential. It must, however, be borne in mind, that the electricity in a lightning discharge is of a very high potential, and can readily overcome the resistance offered by water or moist earth. The moist routes selected by lightning discharges while passing through the air, over buildings, and in the earth, and the fact that well-moist earth is not torn up thereby, fully demonstrate that water and moist earth offer an easy path for said electricity, when a suitable quantity is present.

In order to effect proper protection, the lower terminal of a lightning-conductor should be in the earth to the depth of at least ten feet, and have not less than six square feet of metal surface in contact with well-moist clay, gravel, or sandy soil.

It is principally owing to the small quantity of metal contained in the earth terminals of the lightning-conductors now erected, also the dry condition and poor conductivity of the earth and stone walls around and beneath them, that they cannot be relied upon for the safe passage of electricity in heavy lightning discharges.

When lightning-conductors having a proper quantity and area of metal are employed in short and direct lines across or beneath the roofs of buildings in radial systems, as hereinbefore described, and are well connected, electrically, with the earth, damage to buildings and injury to persons therein will be effectually prevented.

The Latest Lightning-Rod Humbug.

Of the many worthless devices employed for the protection of buildings, etc., from lightning, that suggested by Mr. J. C. Chambers, of Newport, Ky., and recently introduced in the Western States, is the most unscientific and absurd.

It consists of an iron rod placed along and above the ridge of a building, with points at each end projecting upward, and is supported upon large glass insulators, as shown in Fig. 18, and has no rod connecting it with the earth, or any electrical connection with the building.

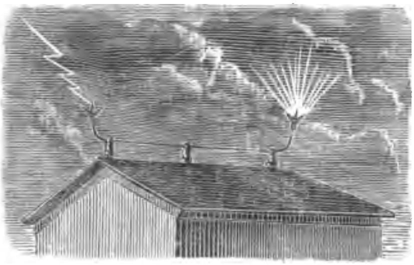
Fig. 18.

According to a pamphlet issued by the Chambers' National Lightning Protection Company of Cincinnati, O., the purpose of the said rod is "to prevent a stroke of lightning by keeping the potentials equal, or so nearly so as to prevent a disruptive discharge from the clouds, or, in case it failed to equalize the electric tensions, and there should be a disruptive discharge toward the house, it would be very feeble and received on one of the points and thrown back into the air in a diffused state from the other points, as illustrated by the above cut."

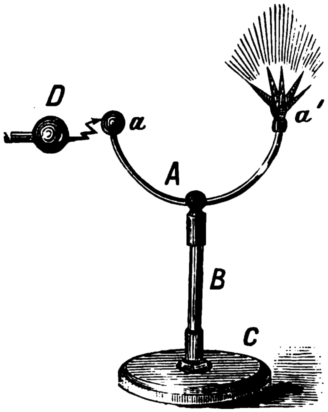

Fig. 19.

The latter-named action is represented as being based upon an experiment shown in Fig. 19, in which it is claimed that when one end, *a*, of curved metallic rod, A, which is supported by upright, B, and wooden base, C, is applied to the charged prime conductor, D, of a frictional electrical machine, the electricity therefrom will flow out of the opposite end, *a'*, in the form of a brush, as shown.

Experience has fully demonstrated that, owing to the great height and area of the thunder-clouds, the function of keeping the potentials of the electricity of the clouds and earth equal, cannot, as a rule, be accomplished even by a rod well connected with the earth, and much less by one disconnected therefrom.

As previously explained, an experiment with artificial electricity is not a proper and practical illustration of the action of the electricity of the clouds and earth while uniting in a lightning discharge. The Chambers' experiment, shown in Fig. 19, does not indicate the path which would be taken by the electricity of a lightning discharge when it takes place in line with an insulated horizontal conductor.

The Chambers' lightning-rod bears about the same relation to a building as a metal chimney-cap upon a chimney, a metal railing on a wooden roof, a metal roof electrically disconnected from the earth, a stove with its pipe leading into a chimney, or any other isolated metal conductor upon the inside or outside of a building.

The many instances where such isolated metallic conductors about buildings have been polarized during a storm, and selected as part of the path taken through buildings by the electricity of the clouds and earth while uniting, fully demonstrate the fallacy of the Chambers' lightning-rod. If any building having the said rod thereon has been uninjured by a lightning discharge in line therewith, as is claimed in the said pamphlet, its protection has, beyond doubt, been due to a metal roof electrically connected with the earth, either directly or through a large flow of water from the rain-pipes at the time of the discharge, or by means of other vertical metallic conductors about the building.

In the said pamphlet it is also erroneously claimed that "Solomon's Temple, that stood for one thousand and eighty-two years in a land of thunder-storms, was protected precisely on the same principle that J. C. Chambers now proposes to protect our dwellings." The protection of the said building, which was fairly exposed to the violent thunder-storms which prevailed in Palestine, is explained as follows: The roof thereof was made of cedar wood, which was covered with thick gilding. In order to prevent the birds from alighting upon and defiling the gilding upon the roof, long upright spears of steel, pointed and gilded, adorned the roof. These metallic spears connected with the thick gilding of the roof, and the gilding connected with the metallic rain-pipes, which terminated in the water-pools under the porch of the temple, thereby constituting, not by design, but fortuitously, a reliable combination of lightning-conductors.

A similar instance is found in the case of the cathedral at Geneva. This building, the most prominent and elevated in the city, has for about three centuries enjoyed a perfect immunity from damage by lightning, while the bell-tower of St. Gervais, situated much lower than the cathedral, has frequently been damaged. This is owing to the great central tower of the cathedral, which is built of wood, being covered from its summit with tinned iron plate, and connected at the base of the tower with the metal covering upon the roof; the latter-named covering being connected with metal rain-pipes, which communicate with an extensive system of ordinary iron drain-pipes imbedded in the earth, thereby constituting a radial system of metallic conductors from the highest projection to the earth, which enables the electricity of the clouds and earth to properly unite without causing damage to the building.

Many other instances can be given where absolute protection to buildings has been effected by means of a metal roof and the rain-pipes electrically connected with the earth.

The Chambers' Lightning-Rod has also been condemned by the most prominent electricians and scientific journals.

The following adverse opinions in reference to the said rod are taken from *The Manufacturer and Builder*, of February, 1880:

"*From Prof. Loomis, of Yale.*—Very dangerous. It is of no value whatever for protection, and, so far as it produces any effect, it would tend to attract the lightning from the clouds, without affording any medium for transmitting the electricity safely to the earth. Nobody but a charlatan would recommend a lightning-rod which had no metallic connection with the earth.

"*From Prof. Young.*—If it has no thorough connection with the ground, it is worse than useless—an absolute invitation of danger.

"*From Prof. Rowland.*—It is the worst humbug that has appeared in this line, and the proprietors of the patent should be arrested for selling the rod under the false pretence that it will protect a building.

"*From Prof. Clarke.*—It is absolutely useless. In theory, it rests upon the total misapprehension of some of the simplest physical laws. I have investigated it thoroughly. I have seen the Chambers' experiment, and know that no scientific man would endorse it for a moment.

"*From Dr. Kedzie.*—It is a scientific humbug.

"*From Prof. Anthony.*—It is worse than useless. It would increase the danger.

"*From Prof. Harvey.*—My opinion is that it might be ornamental, but that it is worthless, if not dangerous. Better have nothing at all.

"*From Prof. Rood.*—Worse than useless.

"*From Prof. Trowbridge.*—I think it is a humbug; for the discharge would not respect the details between the rod and the building. Moreover, the electrical discharge will not necessarily strike such a rod in preference to the larger conductor which the building affords.

"*From T. A. Edison.*—I do not wish to be drawn into any controversy on the subject, but will simply state that the rods on my buildings all connect with the earth.

"*From Prof. Davies.*—I should regard it as I regard much of the iron ornamental work put upon towers and around houses—that is, as adding to the risk of being struck by lightning.

"*From Prof. Silliman.*—That it is in flagrant violation with every accepted principle of electrical science, and should be prohibited, if need be, by legislative enactment.

"*From Prof. Todd.*—I should think it admirably planned for drawing the electric discharge through a building.

"*From Prof. Le Conte.*—Such rods would afford no protection; on the contrary, they would be dangerous.

"*From Prof. Newcomb.*—If it has no connection with the ground, I should not like to be under it during a thunder-storm."

"*From Prof. Pickering.*—I should not use it.

"*From Prof. Mayer.*—From the description given, I should say that the Chambers' rod is utterly useless.

"*From Prof. Macomber.*—I denounce it as a humbug and fraud."

OPINIONS OF PROMINENT ELECTRICIANS, SCIENTISTS, AND JOURNALS.

THE following are selected from a large number of favorable opinions that have been given on Spang's Treatise on Lightning Protection and Improved System of Lightning-Conductors.

From Thos. A. Edison, Menlo Park, N. J., who is known as an eminent Electrician.

Mr. Spang is the best authority in this country on the subject of lightning protection.

From George B. Prescott, late Electrician Western Union Telegraph Company.

I trust that the work will aid in bringing about a much needed reform in the matter of which it treats.

The methods of protection recommended are simple and comparatively inexpensive, and may be practically carried out by any intelligent mechanic, while at the same time they would without doubt prove an effective safeguard, as the principles upon which they are based are in accordance with the known laws which govern the accumulation and discharge of atmospheric electricity.

From the "Journal of the Telegraph."

Mr. Spang, who is known as an able electrician as well as practical telegrapher, has devoted much time and study to the subject of efficient protection against the effects of atmospheric electrical discharges, the results of which are presented in this publication, which is by far the best work that has been published on this important subject.

We fully agree with the author that a system of conductors thus arranged (referring to the employment of rain-pipes, etc., with perforated iron pipes) would unquestionably afford absolute immunity from damage to persons or property from lightning in a building protected by them, and this at a much less expense than is incurred by the erection of the worthless, and in most cases absolutely dangerous contrivances with which ignorant and unprincipled agents have covered houses and other buildings without number in every town and village in the land.

From Latimer Clark, London, England, a distinguished Electrician.

It is beyond all question the best and most complete book on the subject I have seen. I am very glad to see that you expose the fallacy of pointed lightning protectors. It is true that points do no harm, but I quite agree with you that they also do no particular good, and I think you have done good service in stating the fact so clearly.

From Prof. S. F. Baird, Secretary Smithsonian Institution, Washington, D. C.

I shall take pleasure in commending the work to the attention of all persons interested.

From Prof. G. F. Barker, University of Pennsylvania, Philadelphia.

It is altogether the best book issued on the subject. The plan of protection proposed is founded on correct principles, and will be effective.

From Henry Van Hœvenbergh, Electrician, New York.

I consider buildings protected according to the plans suggested as nearly perfectly safe as can be accomplished by human foresight and experience.

From Geo. G. Ward, Superintendent Direct Cable Company, New York.

I consider your system of lightning-conductors an excellent one.

From C. T. Sellers, late Superintendent Philadelphia, Reading, and Pottsville Telegraph Company.

The employment of a metal roof and its rain-pipes, with the improved earth terminal, as suggested, will effect absolute protection, and if generally adopted, damage to buildings by lightning would become a thing almost unknown.

From S. D. Field, Electrician, New York.

The use of perforated iron pipes as earth terminals for lightning-conductors, is a step in the right direction.

From Geo. F. Milliken, Electrician, Boston, Mass.

A work of extraordinary merit; highly entertaining and instructive.

From Prof. John Wise, the Veteran American Aeronaut and Meteorologist.

It contains all that can be said with any degree of certainty in reference to lightning protection. The author is doing the age good service in exposing the quackery of lightning-rod erection.

From the "Manufacturer and Builder."

We recommend the book highly to all who may be interested in this subject, such as architects, builders, tinsmiths, gas-fitters, manufacturers, farmers, and property owners. It is, in fact, the first book of this kind which ever came into our hands in which the author has shown that he understands the subject.

From the "Scientific American."

The work will be found useful in many respects, and will no doubt be fully appreciated by all who may have occasion to consult it.

From the "Operator" (a telegraphic journal).

A standard work, and should have a place in every scientific library.

From the "American Exchange and Review" (an insurance journal).

We can heartily commend this work as calculated to produce good results. There is no waste of printing in the issue of this book.

From the "Cultivator and Country Gentleman."

The book is a good, sound instructor, and contains a large fund of interesting matter.

From the "Christian Union" (Henry Ward Beecher's paper).

A sensible book on a subject which has occasioned more wild speculation than any other, excepting perpetual motion.

From the "Reading (Penna.) Times and Dispatch."

Mr. Spang is thoroughly conversant with the subject on which he has written such an admirable treatise. It is written in a popular vein, while the language is such as to render the subject familiar and enable the reader, whether learned or unlearned, to understand the author's meaning.

From the "Cleveland Herald."

A conscientious study of the work will fill with misgivings the minds of many persons who had rested easy during thunder-storms, in the conviction that their property was perfectly protected against lightning.

From the "Philadelphia Inquirer."

If only for one thing, the author of this book deserves well of his country, for, were his ideas acted upon, the lightning-rod man would be abolished from our midst. Mr. Spang does not pin his faith to lightning-rods. His idea is that the electric fluid can be made harmless in another way. That way is too elaborate and wonderful to explain here, but in the book it is expounded with much clearness and forcible argument.

From the "Railway Age."

The book must become authority on the subject of which it so ably treats.

From Jas. Gamble, Genl. Supt. Western Union Telegraph Company, San Francisco.

I should feel much safer, during a thunder-storm, in a building with the entire roof surface of metal properly connected with the earth, than with half a dozen lightning-rods over it.

From E. A. Hill, Electrician, Chicago.

I regard your system as the best, and when properly carried out will give very efficient protection from the destructive effects of lightning.

From the "Columbia (N. Y.) Spectator."

It is a work that has long been needed, and ably supplies the want of knowledge experienced by all classes of men on this subject.

From Hugh Neilson, Superintendent Dominion Telegraph Company, Toronto, Canada.

I cannot find anything in your work with which I do not thoroughly agree.

From Angus Grant, Electrician, Montreal, Canada.

It is the only practical work I have ever seen on the subject, and ought to revolutionize the lightning-rod business.

From the "Prairie Farmer."

The book gives the rational and scientific methods of protection against lightning, and is well worth the price asked for it.

From W. J. Holmes, Supt. Telegraph, Erie Railroad Company, New York.

Your method of protecting buildings by the employment of metal roofs, gutters, and leaders connected with the earth, as suggested, will prove effectual.

From E. P. Wright, Electrician, Cleveland, Ohio.

I consider your system of lightning protection the best that has yet been devised.

From the "North-Western-Lumberman."

The author brings to his work the experience of over eighteen years, of which he has left many evidences in the pages of this interesting volume.

From the "Polytechnic Review."

It is unquestionably the best treatise on the subject of lightning protection that has been produced.

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